

Molecular Foundry Example Proposal #5

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Plasmonic antennas and nanochannels embedded on microresonators for single nanoparticle identification

top

Facilities

Foundry Facilities

Facility	Description
Fabrication: (lead)	Nanofabrication facility will be used to develop a reliable method to fabricate resonating microstructures embedded with nanochannels plasmonic antennas on the same platform. Most of the planned process steps are already done at the Nanofabrication facility.
Imaging/Manipulation: (support)	The Imaging facility will be needed to have a complementary characterization of actual movement of the nanoparticles inside the nanochannels, especially in the first phase, before sending samples to [REDACTED], where the vibrational measurements will be employed

Proposal Description

Significance and Impact

Accurate determination of nanoparticles (NPs) in liquid is a well-recognized challenge for the scientific community. Natural or engineered NPs with diameters below 100 nm are extremely interesting in many fields, such as medicine (drug delivery, imaging, cell-secreted carriers), environment (groundwater remediation), and food (nano-encapsulated ingredients and additives, anti-microbial).

A major aspect concerning food is that in Europe from December 2014 all ingredients present in the form of engineered nanomaterials will have to be indicated in food labels (Regulation 1169/2011), while it is well known that the determination of NPs presents extremely serious analytical challenges for definition of identity (whether a certain substance is in the sample, i.e. size and chemical composition) as well as quantification (how much of the substance is in the sample, i.e. mass). Currently used techniques such as TEM, DLS and ICP-MS pose severe limitations in sample preparation, cost and data interpretation, so it is clearly evident that there is a strong need for an analytical technique that should be able to satisfactorily and routinely measure the number and particle size distribution of objects in the 1-100 nm size range.

We here propose to develop an innovative analytical platform, based on a resonating microstructure on which one or more nanochannels and plasmonic antennas are embedded (a sketch is reported in figure 1). The nanochannels will be fabricated of different dimensions (10-100 nm), so a first sorting of the characteristic dimension of the nanomaterial will be made. When passing the center of the bridge, the NP will produce two effects: a modification of the local refractive index between the plasmonic antennas and a variation of the local resonating mass. The first effect will be used to count the NPs, the second to weight them. If needed, the liquid will be changed and the resonant frequency re-measured, in order to separate the NP buoyant mass from the liquid mass, and thus having an indication of the NP density (i.e. an indication of the chemical composition).

We already performed finite element simulations that showed measurable frequency shifts even for NPs of 1 nm of radius, while a first simplified prototype was successfully fabricated by Nanofabrication facility and vibrationally characterized at [REDACTED]. Such preliminary results show the feasibility of the proposed approach.

Apart from the above-described diagnostic goal, a similar tool would be very useful for any research related to synthesis, characterization and use of NPs.

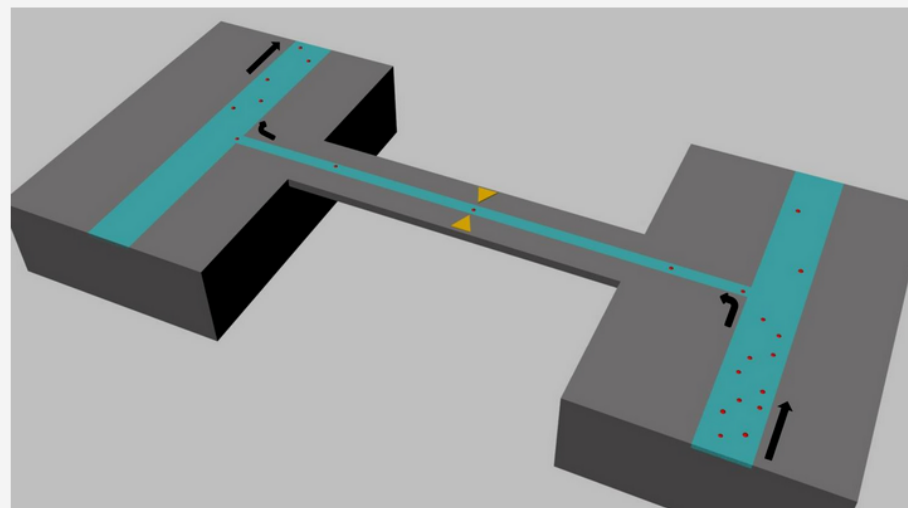


Fig.1 Sketch of the micro-resonator embedding the plasmonic antennas and the nanochannel

Project Plan

The experimental activity can be easily divided into three Tasks:

T1 - Device design and simulation

T2 - Device realization

T3 - Device characterization

T2 is the core of the project and will be entirely done at the Foundry; T1 and T3 mostly at [REDACTED]

Device design (T1) will be based on a finite element analysis that will define an optimized geometry for highest mass and optical sensitivity, given the constraints of fabrication and characterization techniques. A first model has been already developed at [REDACTED] for vibrational mechanics and fluid-structure interaction, while plasmonic antennas simulations have already been performed at the Foundry.

The fabrication of the resonating device embedding the plasmonic antennas and the nanochannels will be entirely performed at the Nanofabrication facility (T2). It's worth noting that most of the process steps have been already optimized at the Foundry for a different analytical device, so a relatively small effort will be needed to adapt them to the here-proposed device. A master stamp will be fabricated on silicon substrate with standard lithographic processes to define a reverse image of the resonator and of the nanochannels. The template will be used to replicate the device with two gold plasmonic antennas deposited by sputtering. Then the sample will be bonded with a SiN layer to seal the nanochannels, and patterned with wet-etching (Figure 1). The resonators will then be bonded with a PDMS microfluidic platform to handle the fluid movement into the nanochannels.

We have already tested together with the Nanofabrication facility staff the feasibility of the imprinting process by fabricating a first prototype of resonating microbeam, actually without the nanochannels and the plasmonic antennas. We were able to obtain a robust structure and to identify its resonance curve, as shown in figure 2.

While the complete characterization of the analytical platform will be performed at [REDACTED], preliminary tests concerning effective micro/nano-structures release and NPs flowing will be performed at the Foundry. To this aim, the access to the Imaging and Manipulation facility will be fundamental. An *ad-hoc* measurement set-up that uses the same laser source to exploit contemporaneously the functionality of the antennas and of the resonating structure will be set at [REDACTED]. The channels will be filled with solutions containing different NPs and we will test the ability of the antennas to reveal the passage of the NPs and of the microbridge to evaluate their mass.



Molecular Foundry Utilization Timeline

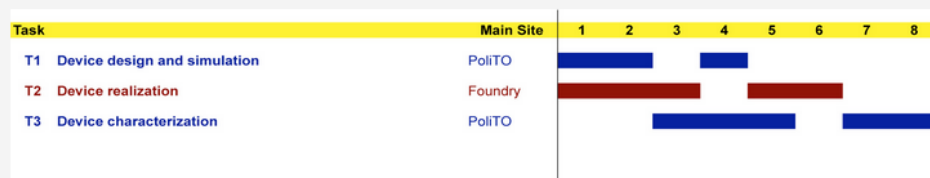
The expected timeline of the project is summarized by the GANNT chart that follows. The whole project will last eight months, five of them at the Foundry.

The first three months will be focused on the fabrication of the sensing device at the Nanofabrication facility together with finite element analyses to define and achieve the design with the highest sensitivity. Dr. [REDACTED] will perform the whole fabrication process of the microresonators with plasmonic antennas and nanochannels, with the help of the Molecular Foundry staff. Since most of the process steps have been already optimized at the Foundry for a different analytical device, we expect to have a first prototype that can be fully characterized as analytical device by the end of month three.

Then, using the achieved experimental results as inputs in finite element simulations, new optimized designs will be proposed and tested. We expect to have a second high-performing prototype by the end of month six.

The remaining period of time (two months) will be focused on exploiting the performances of the developed device as an analytical instrument. The devices will be filled with different fluids containing several NPs that could be found as contaminants in foods, in order to validate the applicability of the proposed sensing platform. Limit of detection (LOD) and limit of quantification (LOQ) will be evaluated.

Finite element simulations and complete device characterizations will be employed by Dr. [REDACTED] and his research group, mainly at the host institution.



Relevant Experience

Name	Scientific role	Experiences
Dr. [REDACTED]	Project Leader	Dr. [REDACTED] graduated in Physics in 2000 and got his PhD in Physics in 2004. He has an international reputation on design (Finite Element modeling), fabrication and characterization (both static and dynamic) of micro/nano-mechanical sensors. He has a relevant experience on developing analytical tools based on microcantilever array biosensors for the detection of small molecules (mycotoxins, hormones, DNA), proteins (cancer markers) and whole bacteria (Salmonella, E. Coli).
Dr. [REDACTED]	Primary Researcher	Dr. [REDACTED] received the master degree in Nanotechnology Engineering and the Ph.D. in Physics from [REDACTED]. He has a relevant experience in fabrication, characterization and integration of sensor, mainly based on piezoresistive and piezoelectric materials. More recently he has worked on the fabrication of resonating microstructures (such as cantilevers and bridges) and in their application as diagnostic tools in medical and agro-food sectors. He has also an adequate experience in the synthesis of metallic nanoparticles.

Need for the Molecular Foundry

We are strongly motivated in performing the project at the Molecular Foundry mainly for their well-recognized experience on fabrication and manipulation of nanostructures, but also for the possibility of sharing our ideas into a so multidisciplinary and skilled environment.

It is important to underline that a part of the here proposed analytical device - the nanofluidic channels with plasmonic nanoantennas - is currently fabricated and tested at the Nanofabrication facility. This know-how perfectly matches with our consolidated expertise on fabrication and characterization of resonating microstructures as diagnostic tools for medical and agro-food applications. Moreover, the capability of characterizing and manipulating nanostructures at the Imaging and Manipulation facility will be fundamental to perform preliminary tests concerning effective localization of the NPs, without coming back or sending samples to the host institution. These two aspects strongly contribute to guarantee the feasibility of the proposed project and to speed-up the experimental activity.

As underlined in the first section, the present project could have a significant impact on all the research fields in which biological and inorganic nanostructures are synthesized, characterized and used. Therefore, we expect to have fruitful interactions with people from Inorganic Nanostructures and Biological nanostructures facilities.

All the cited aspects, together in the same place, are clearly a unique feature of the Molecular Foundry.